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THE GRID- A POSSIBLE RESULT OF THE APPLICATION OF FIBER OPTICS --ETC(U)

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THE GRID — A POSSIBLE RESULT OF THE APPLICATION OF FIBER OPTICS TO UNDERSEA SURVEILLANCE: SOME POTENTIALS AND THE CONCEPT

FP Armogida

March 1980

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INTRODUCTION

Fiber optics currently is making a big splash. It's everywhere: tethers for guided weapons, internal communications in ships and aircraft, land line communications, acoustic sensors, etc. The applications for fiber optics will grow rapidly as its costs decrease and familiarity and availability increase. With its obvious advantages to communication trunk systems, one does not need a crystal ball to know that fiber optics will make a major impact on undersea surveillance. However, the intent of this paper is not to define what the major impact is, but rather to stimulate thought on the impending "wet end revolution," as it has been named by Dr. George Hetland of PME-124. *This revolution will come about because fiber optics potentially can alleviate three problems associated with undersea communication cables: high cost, lack of flexibility, and vulnerability.*

FIBER OPTIC TECHNOLOGY TODAY

To help clarify the time frame and extent of the impact, I will review for you where fiber optic technology is today. I will do this in two ways: first, by examining fiber and fiber optic system technology availability in Japan and North America; and second, by noting two futuristic efforts: ultra-low-loss fiber and air-deployed surveillance.

The attenuation and dispersion characteristics of the optical fiber are the most important indicators for the state of the art. This determines the repeater spacing for a given bandwidth, and hence a driving cost of a long haul system. Figure 1 illustrates the attenuation characteristics for three selected fibers. Curves A, B, and C illustrate fiber presently available in the United States and Japan. The Japanese have the lowest loss fibers available in the world today.¹ In the 1.55- μ m wavelength region, attenuation-limited systems (50 dB) could be built with a repeater spacing on the order of 250 km. The United States lags behind Japan in fiber technology by one to three years. Figure 2 delineates the bit rate and unrepeated length of laboratory and field trial fiber optic systems operating in Japan and North America. Japan clearly has the lead, due to its fiber technology.

Now I would like to note two relatively futuristic efforts. The first is project Clearday at DARPA. This project will initiate research for developing fibers which promise 0.01 dB/km, or better. The potential is repeaterless trunks for fixed undersea surveillance applications. The second relatively futuristic effort is air-deployed surveillance, which has been initiated at NOSC just this year. The effort is aimed at demonstrating aircraft (C-130/141) deployment of a repeatered fiber optic cable which is suitable for undersea surveillance applications.

1. See references, page 10.

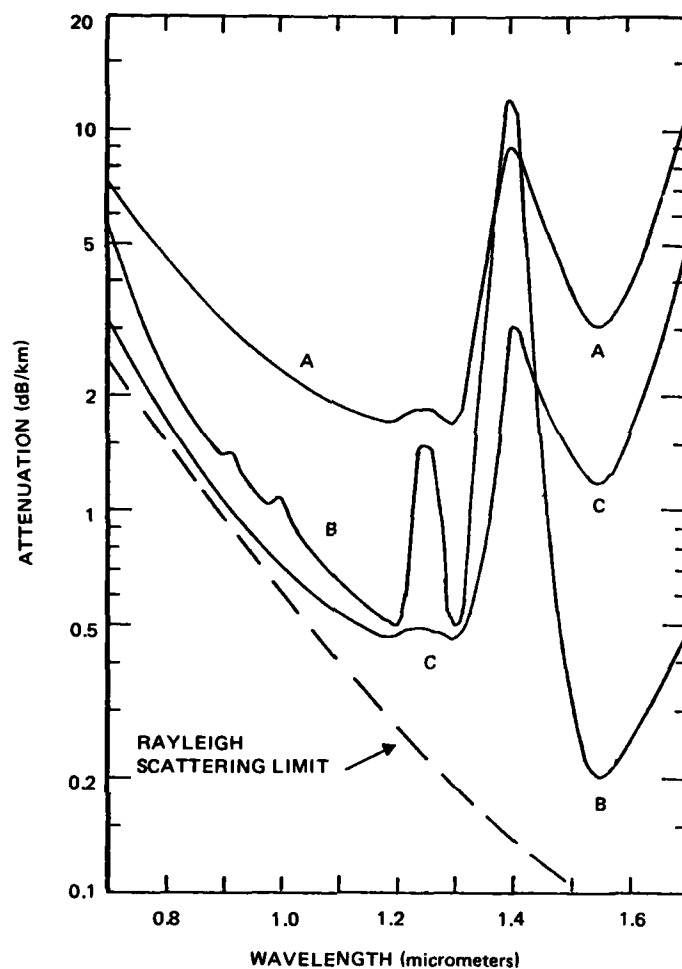


Figure 1. Examples of current (1979) optical fiber attenuation. Curve (A) is typical of best U.S. commercial capability, while (B) and (C) represent ultra-low-loss fibers reported by Japanese scientists.

LOCATION	BIT RATE	WAVELENGTH	UNREPEATED LENGTH	COMMENTS
Japan	100 Mb/s	1.3 μm	53 km	Quarterly Laser Diode Source ²
	32 Mb/s	1.32 μm	90 km	Solid State Laser Source ³
North America	44.7 Mb/s		7 km	T-3 Telephone System ⁴
	274 Mb/s		3.5 km	T-4 Telephone System ⁴

Figure 2. Fiber optic systems demonstrations and field trials.

THE GRID

With this brief review of fiber optic technology in mind, it is not difficult to speculate about fiber optic trunks for fixed system applications. Fiber optics may be the vehicle for providing a low cost fixed system capability which is both flexible and survivable by design. The key considerations are:

- (a) To reduce costs relative to coaxial cable systems.
- (b) To maintain the diameter advantage of fiber optics.
- (c) To conceptualize a system which can keep pace with variations in the military and political areas of interest by either shifting or expanding.
- (d) To reduce vulnerability through such means as gridding or constant change.

Contemplating these considerations, I have postulated a system based on a grid. A grid, illustrated in figure 3, is simply a communications and/or power network which is cross connected for access and survivability. To determine the parameters of a grid for undersea surveillance, I considered two questions:

- 1. What would be the requirements if the grid were to be global in nature?
- 2. What would be the characteristics of the grid components?

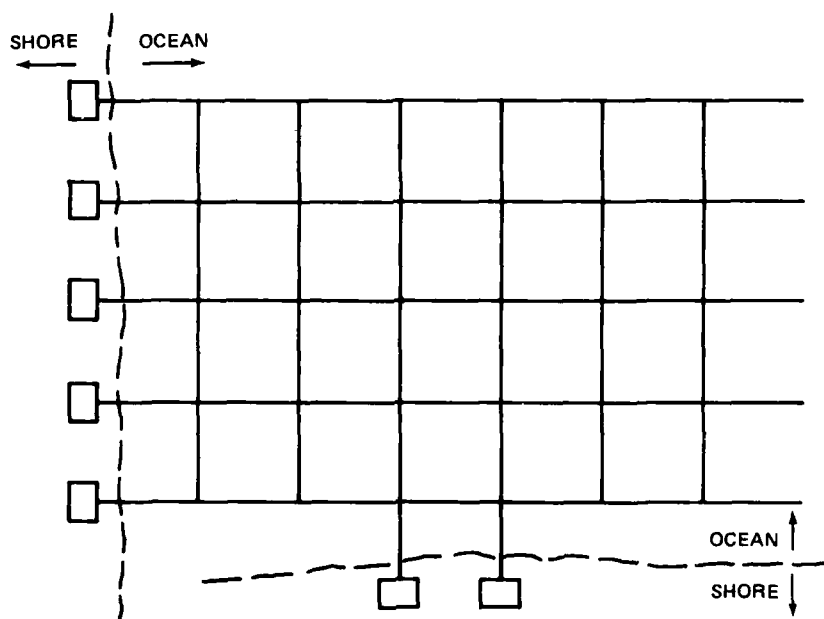


Figure 3. The grid concept — a cross-connected network of undersea cables.

Addressing the first question, I made the following assumptions:

- (a) An average sensor density of 1 per 1150 square kilometers (625 sq nm), and three-fourths the surface area of a globe 14,825 km (8000 nm) in diameter.
- (b) An average grid density of 186 km sq (100 miles square); that is, some sensors are distributed and some are clustered.
- (c) A sensor bandwidth average of 2000 Hz, requiring 8-bit resolution with a sample rate of 3000 Hz.

The results follow:

- (a) $\approx 250,000$ sensors
- (b) 5.6×10^6 km (3×10^6 nm) of cable with 15,000 nodes (cross junctions)
- (c) A total sensor bandwidth of 6×10^9 b/s; adding 50% for grid overhead ≈ 10 Gb/s.

A system of this magnitude could take decades to implement and thus requires components which can readily accommodate new generations of technology. This brings me to the second question. Keeping in mind the key considerations and moderating the scope with "some" realism, I have postulated the following components:

- (a) The 200-km, full-duplex, 274 Mb/s (T-4 rate) cable section – illustrated in figure 4A, containing a 2-mm-diameter optical cable and a split duplex repeater. As illustrated in figure 5, the split repeater contains a pair of receiver/transmitters which are interconnected via an underwater mateable connector. The connector must transfer power and telemetry bidirectionally and provide mechanical strength.
- (b) The sensor module – illustrated in figure 4B, containing a sensor cluster, a projector, and a battery, as a minimum.
- (c) The cross junction – illustrated in figure 4C, containing a port controller and a sensor module, as a minimum.

The advantages and disadvantages of the grid fall into three categories: (a) improvements, (b) additions, and (c) vulnerability. The improvements over the present coaxial cable systems include the fact it is survivable. That is, referring to figure 3, the grid can stand a high percentage of destruction and still function effectively. It is maintainable. The grid can be updated and repaired. It is flexible. It can be deployed by air, submarine, or surface ship and can be modified by submarine. It will cost much less than coaxial cable, and the electronics can be adapted from T-4. The additions potentially include the following:

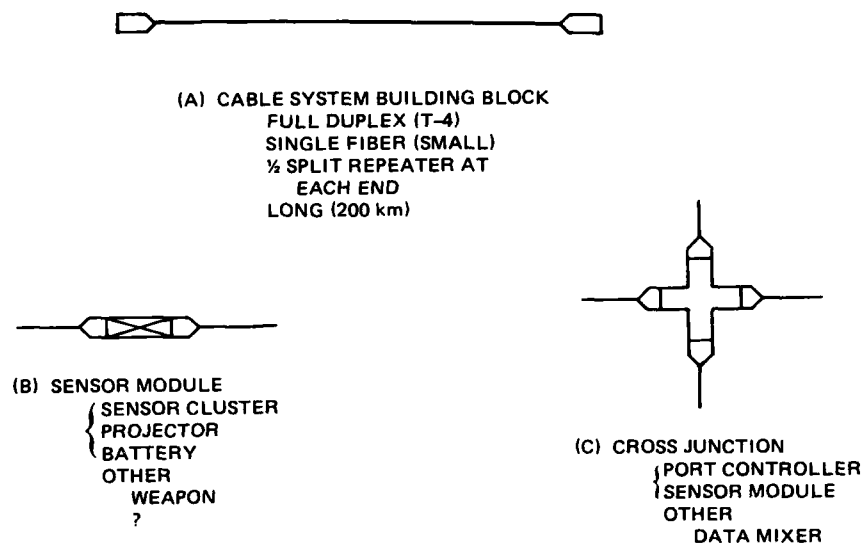


Figure 4. Grid components.

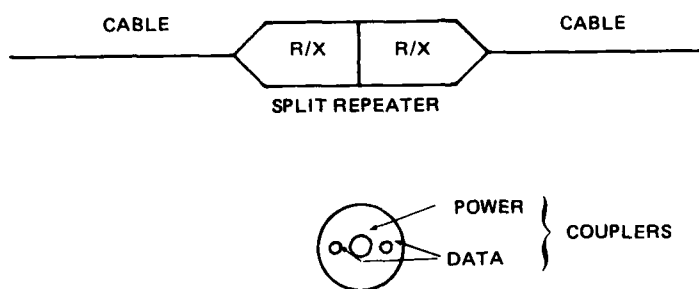


Figure 5. Details of split repeater.

- (a) Command active surveillance
- (b) C³ (vectored intercept)
- (c) Navigation
- (d) Remote control of weapons
- (e) Ship use

The only vulnerability which has surfaced so far is control of the grid. The problem is that with accessibility comes the threat that someone other than friends will use the phone. Can we control a grid?

I have prepared two examples of the grid; a close focus (near term) and a far focus (long term). Present surveillance systems are generally cabled to shore in small groups at widely spaced points, as illustrated in figure 6A. Near term: gridding techniques would result in a cross connected structure which provides survivability in terms of a few cable breaks and shore facility losses (figure 6B). Long term: the following scenario may result. An aircraft out of Adak deployed a distributed system, 5000 km long, down the coast of the Soviet Union. A submarine (or surface combatant) transiting from Pearl Harbor to the Vladivostok area interconnected two pairs of trunk lines, patched into the southern end of the air-deployed Adak cable and, proceeding to lay cable, continued to the Vladivostok area. Note that during the deployment periods the deployment vehicle becomes an integral part of the grid. That is, the deployment vehicle sensors could be available to grid shore facilities, as well as grid sensors being available to the deployment vehicle.

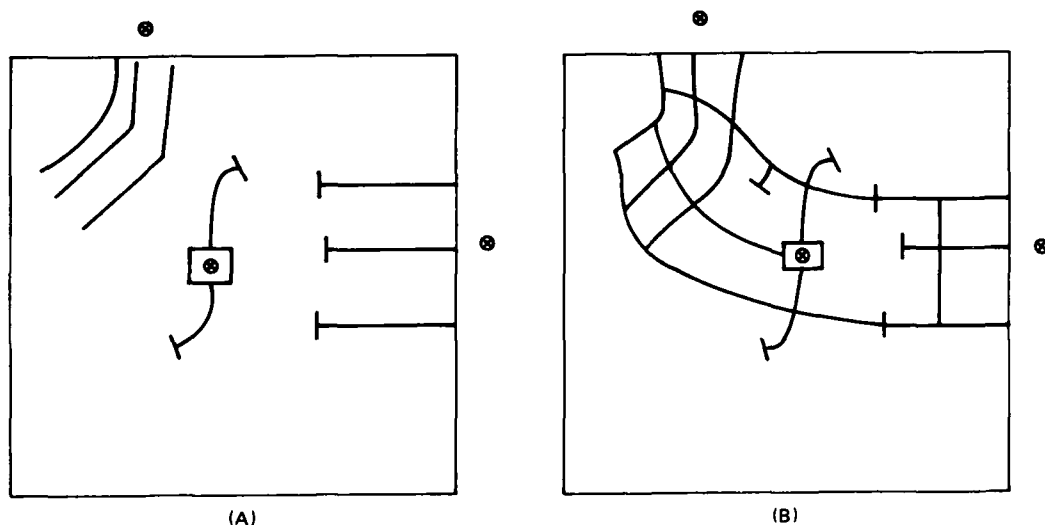


Figure 6. Surveillance systems (A) without grid techniques and (B) with grid techniques.

COMPONENTS WHICH SHOULD BE DEVELOPED

The following components could be specified now to determine the technology shortfalls:

- a. Long-life, single-mode, long-wavelength sources and detectors
- b. Long, low-loss, strong, single-mode fibers
- c. Power sources
- d. Split repeaters
- e. Junctions
- f. Transducers
- g. Weapons
- h. Sensors

However, I feel that such a specification would go far beyond the original intent of this presentation.

CONCLUSION

As originally stated, the objective of this presentation was to stimulate thought on the "wet end revolution." In conclusion, I would like to quote from some notes of Don Weigel, Chief Engineer, ASW Aircraft Test Directorate, NATC, which provide some direction.

"... It is at the force level that we seem to ignore technology. We advance the individual systems that comprise the force, but to step back and consider the dictates of technology on that composition seems to be beyond our ability. The effects of technology on force composition are difficult to perceive and cannot be adjudged without evaluation of missions which likewise must be considered in terms of technology. The difficulty of force and mission assessment as a function of dynamic technology cannot be overstated..."

In the face of the "wet end revolution," I believe it is a time for some thought on what we want.

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